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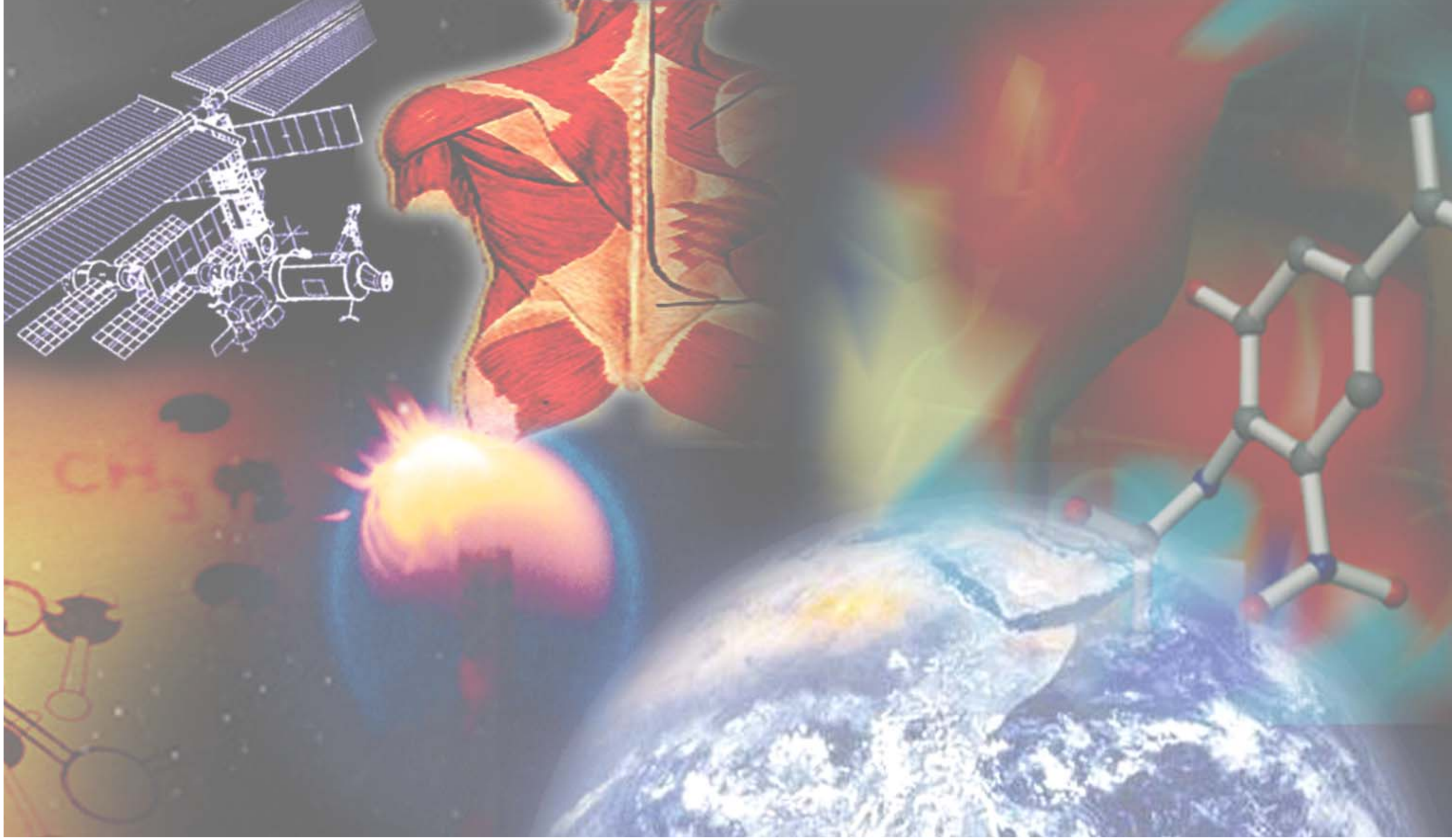

Science on the International Space Station

Guy Fogleman
Director (Acting), Bioastronautics Research Division
Office of Biological & Physical Research

PEOPLE, SCIENCE and TECHNOLOGY in SPACE

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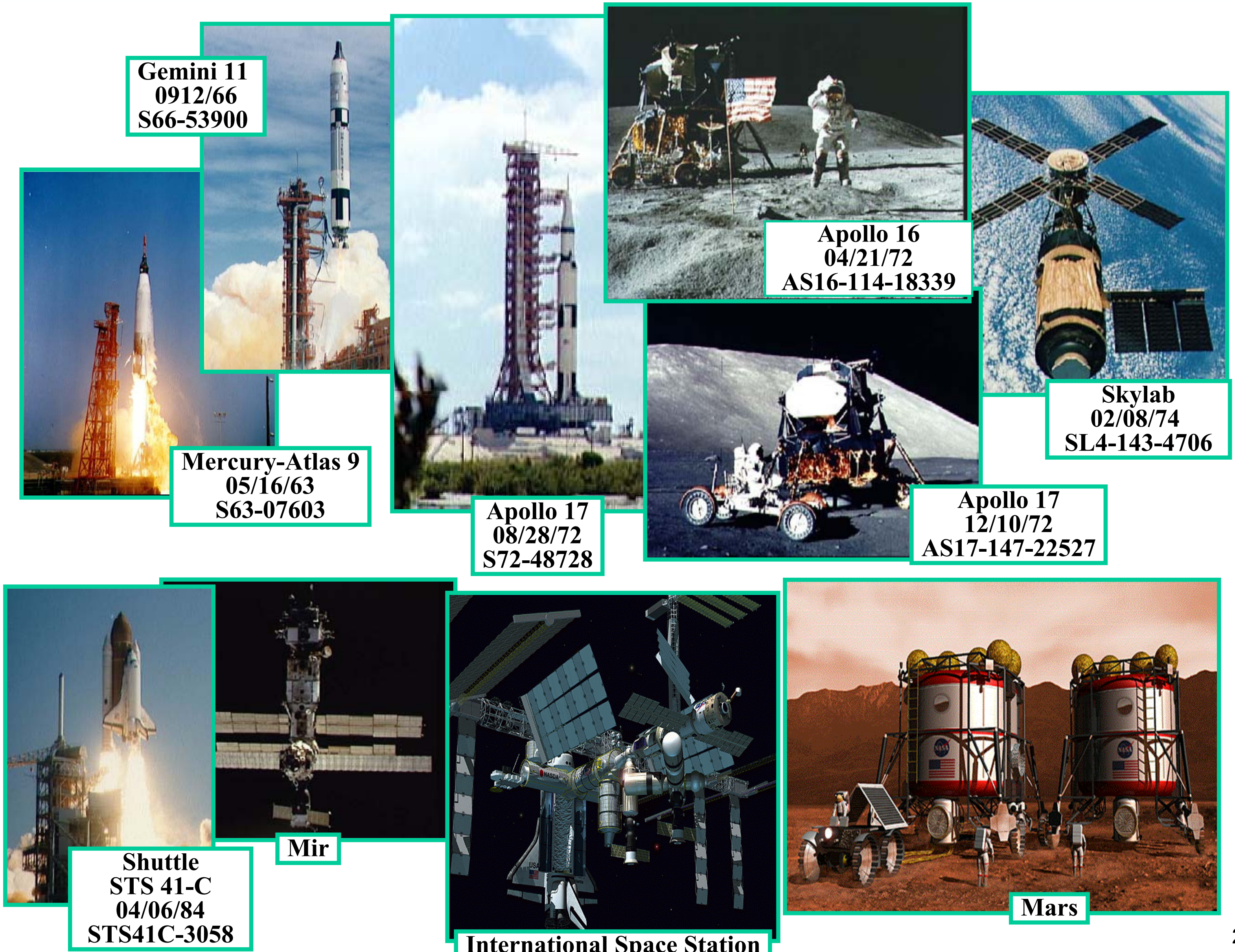

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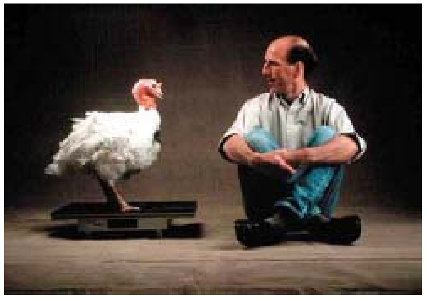
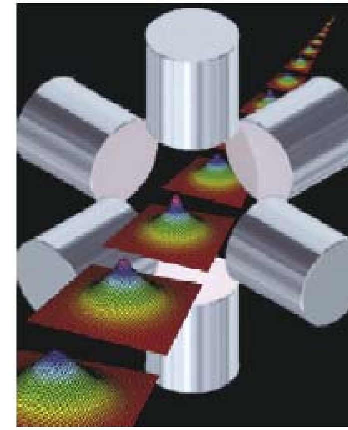
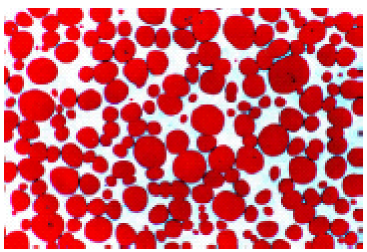
Our Past Orbit: the past 5 years…



Experiments with mild vibrations suggest a possible countermeasure to astronaut bone loss and osteoporosis

Atom Lasers: Nobel Prize in Physics – 2001

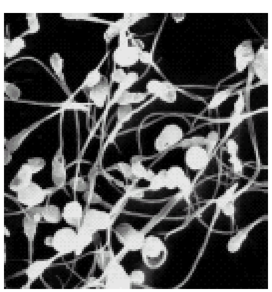




Liquid-Phase Sintering' results used by Kennametal to make their metal-cutting products without expensive post-sintering machining.

OBPR Research has appeared on the covers of major scientific journals and books.

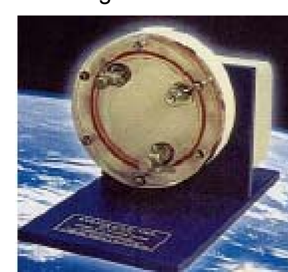
Weakest flames ever observed. Other combustion flight results used by the 2 US aircraft gas turbine engine manufacturers



Gravity sensitive fertilization processes demonstrated

OBPR's cataract early detection device co-sponsored and highlighted by NIH to Congress

Bristol-Myers Squibb and BioServe demonstrated production of antibiotics is substantially greater in microgravity than on earth.



Bioreactors: Over 25 patents and over 6000 units in the US Marketplace

NASA Vision and Mission

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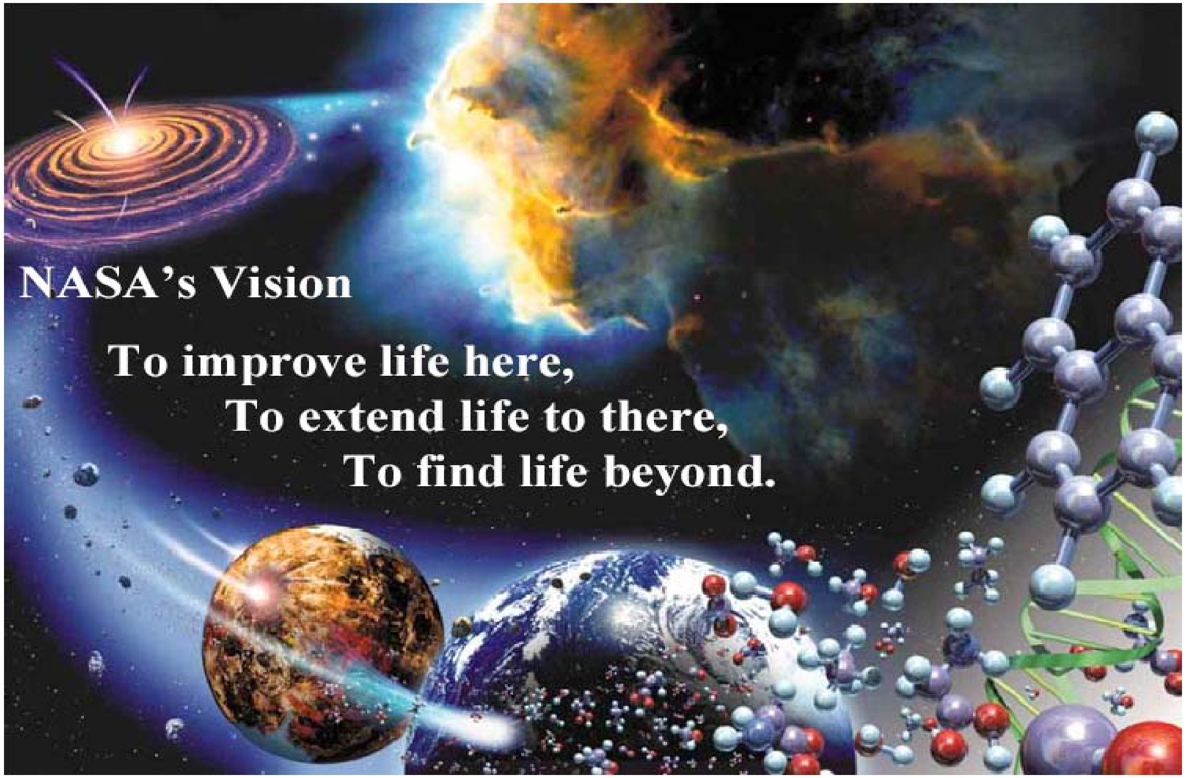


NASA's Mission

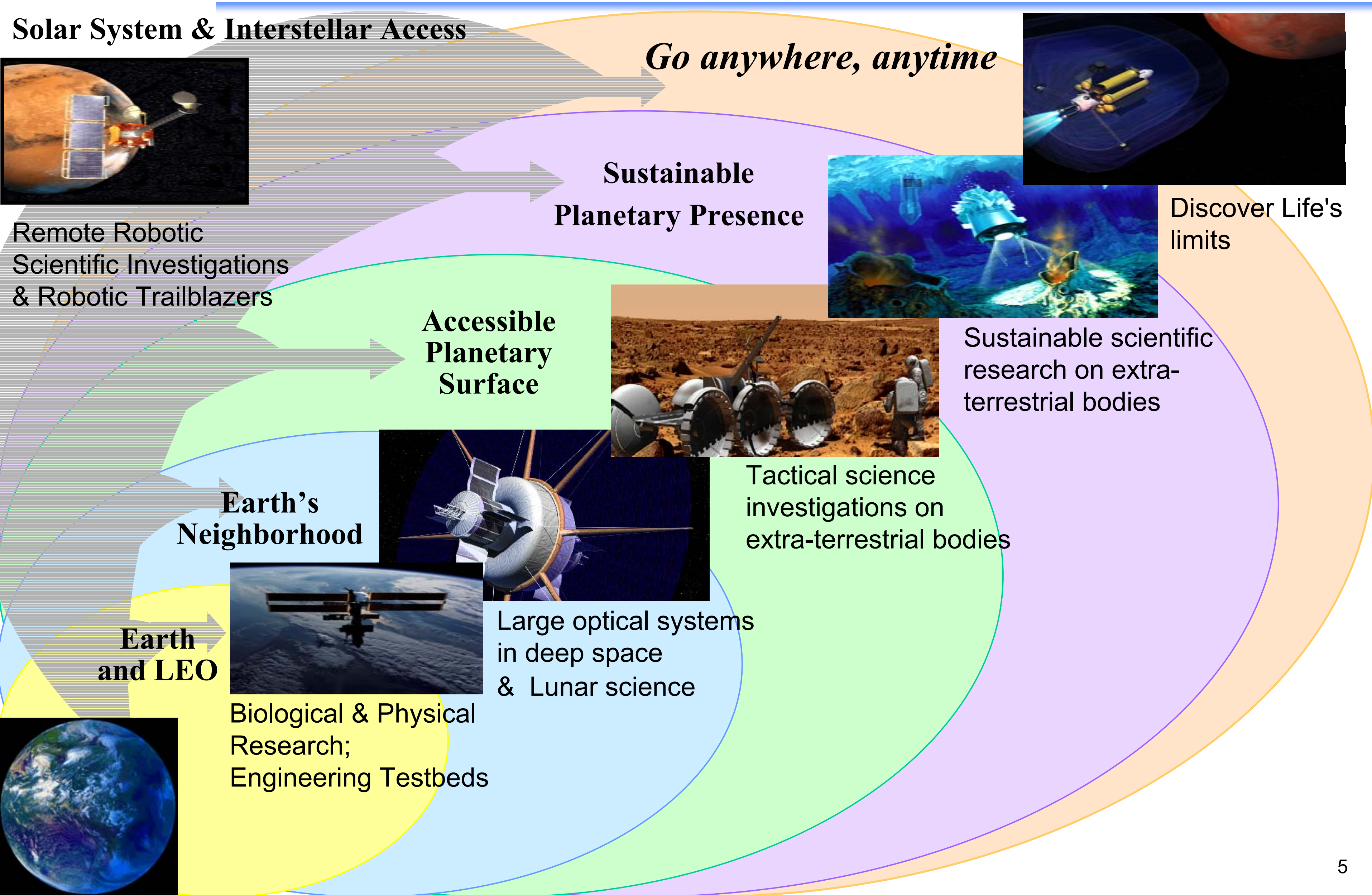
To understand and protect our home planet

To explore the Universe and search for life

To inspire the next generation of explorers

…as only NASA can.

Stepping Stones Exploration Strategy



The Organizing Questions …The OBPR Mission

Humans will extend the exploration of space. To prepare for and hasten the journey, OBPR must answer these questions through its research, principally on the ISS:

How can we assure the survival of humans traveling far from earth?

What must we know about how space changes life forms, so that humankind will flourish?

What new opportunities can our research bring to expand our understanding of the laws of nature and enrich lives on Earth?

What technology must we create to enable the next explorers to go beyond where we have been?

How can we educate and inspire the next generations to take the journey?

Our Current Orbit – And Beyond

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Question 1: How can we assure the <u>survival</u> of humans traveling far from earth?

- ***Question 1a:*** *What knowledge and tools are needed to enable the practice of medicine in space?*
- ***Question 1b:*** *How does the human body and its physiology adapt to space flight, when is it appropriate to counteract those adaptive effects, and by what means can we do so?*
- ***Question 1c:*** *What is needed to protect human space explorers from the cosmic radiation that bombards their spacecraft and bodies?*
- ***Question 1d:*** *How can we provide an optimal environment to support behavioral health and human performance in space flight?*

Biomedical Risks Humans Face in Space

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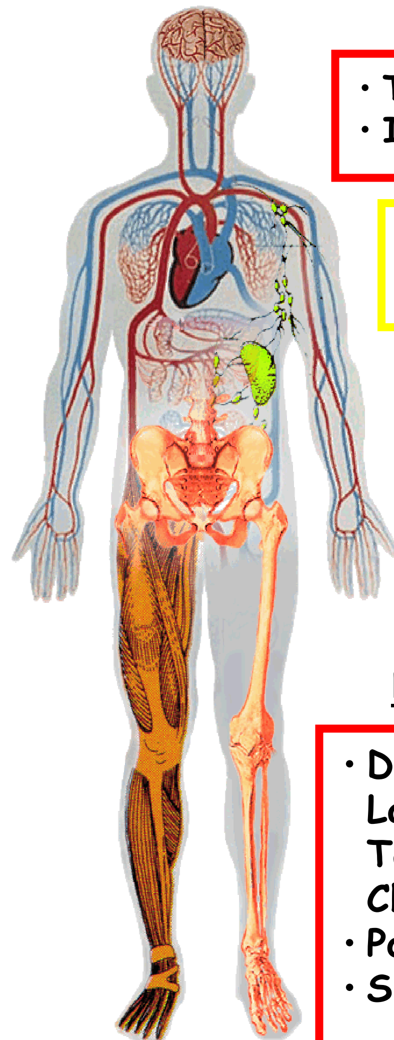
Effects of Radiation

- Carcinogenesis (38)
- Synergistic effects with microgravity or environmental factors (40)
- Late degenerative tissue effects (39)

Physiological Changes

- Carcinogenesis due to immune system changes (23)
- Occurrence of serious cardiac dysrhythmias (13)
- Acceleration of Age-Related Osteoporosis (9)

- Manifestation of previously asymptomatic cardiovascular disease (16)
- Toxic Exposure (44)



Medical Practice Problems

- Trauma & Acute Medical Problems (43)
- Illness & Ambulatory Health Problems (46)

- Renal Stone Formation (12)
- Toxic Exposure (44)

Behavior and Performance Problems

- Disorientation and Inability to Perform Landing, Egress, or Other Physical Tasks, Especially During/After G-Level Changes (33)
- Poor Psychosocial Adaptation (18)
- Sleep & Circadian Rhythm Problems (19)

Biomedical Risks Humans Face in Space and on earth

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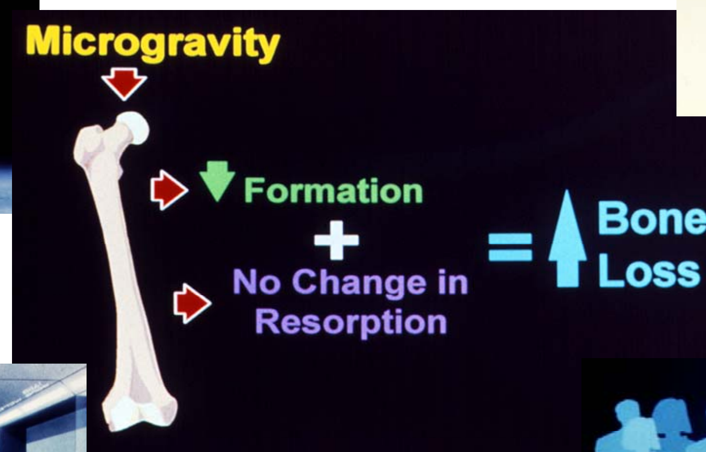
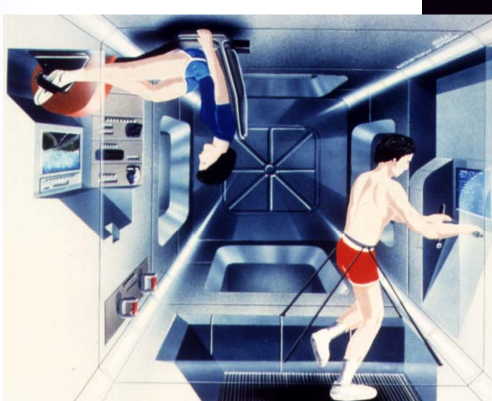
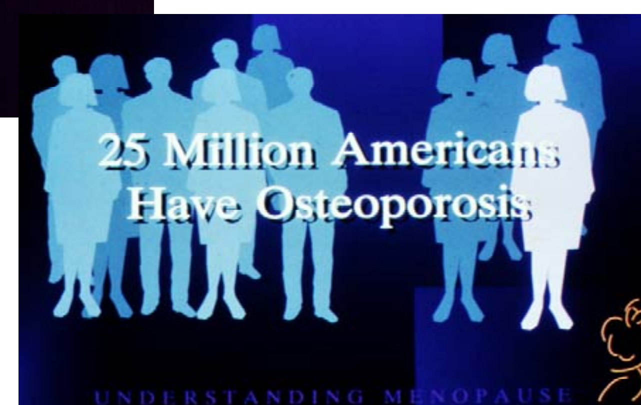
Lost in Space...

Bone and muscle



Aging





Example of ISS Research: The Phantom Torso Experiment

(Increment 2 & Future)

Gautam Badwhar, Ph.D, NASA JSC, TX

This experiment was designed to do three things. First, it determined the **distribution of radiation** doses inside the human body. Second, it provided a **correlation** between internal measurements and those made externally, on the skin. Last, the data supported **models** that predict how the three primary types of radiation that endanger astronauts pass through the human body.

The Phantom Torso onboard the ISS showed that the measured dose of galactic cosmic rays to the skin is an accurate (within 15%) estimate of that to the internal organs, while the skin dose of trapped protons overestimates the dose to internal organs.

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- ***Question 1: How can we assure the survival of humans traveling far from earth?***
    - ***Question 1c What is needed to protect human space explorers from the cosmic radiation that bombards their spacecraft and bodies?***

Picture caption: Fred is the Phantom Torso, a 95-pound, 3-foot high mockup of a human upper body. Beneath Fred's artificial skin are real bones. Fred's organs, heart, thyroid, colon, etc. are made of plastic that matches, as closely as possible, the density of human tissue.

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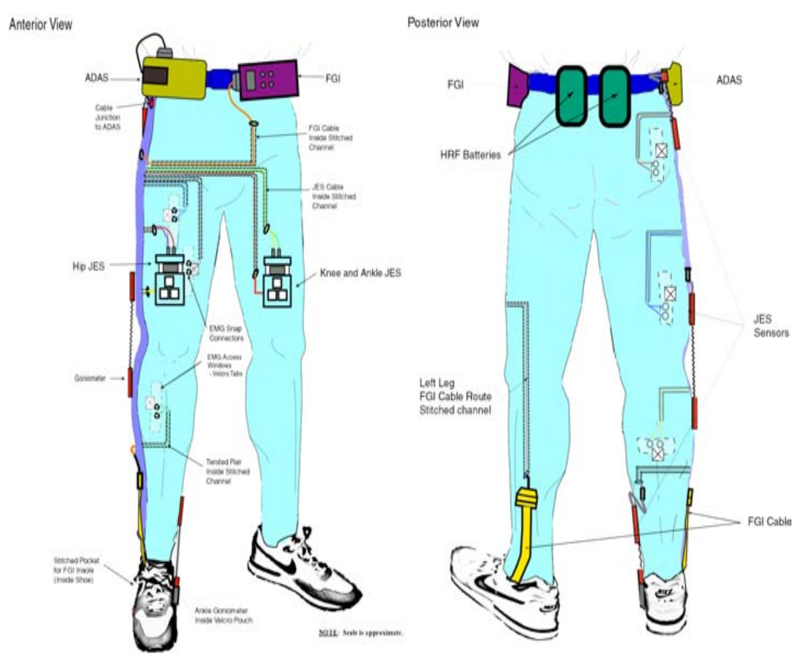
Example of ISS Research
Foot Reaction Forces During Space Flight (FOOT)

(Increments 6, 7, 8 & 9)

Peter Cavanagh, Ph.D.; Cleveland Clinic Foundation, Cleveland, OH

Goal: to characterize muscle activity and load on the lower extremities of crewmembers during long space flight, as they work on ISS.

Pre- and post-flight estimates of bone mineral density, muscle cross-sectional area, and joint torques will provide a perspective against which the consequences of change in activity profiles can be judged. These results support development of countermeasures to lower extremity muscle and bone loss.



Activity Monitor Suit

- ***Question 1: How can we assure the <u>survival</u> of humans traveling far from earth?***
  - ***Question 1b: How does the human body and its physiology adapt to space flight, when is it appropriate to counteract those adaptive effects, and by what means can we do so?***

Our Current Orbit – And Beyond

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Question 2: What must we know about how space changes life forms, so that humankind will <u>flourish</u>?

- ***Question 2a:*** *Does space affect life at its most fundamental levels, from gene to the cell?*
- ***Question 2b:*** *How does long-term exposure to space affect organisms?*
- ***Question 2c:*** *How does space affect the development and life cycles of organisms?*
- ***Question 2d:*** *How do systems of organisms and their interactions change in space?*

Questions Associated with Question-2: What must we know about how space changes life forms, so that humankind will flourish in space?

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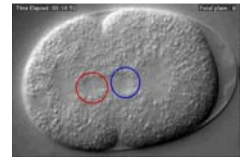
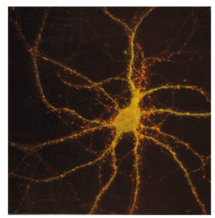
Does space affect life at its most fundamental levels, from gene to cell?

- Cell-to-cell communication
- Intra-cellular functions
- Signal transduction
- Cell cycle and growth
- Genomics
- Proteomics

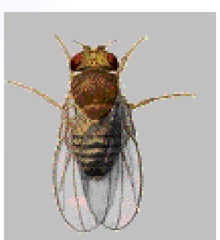




How does long term exposure to space affect organisms?

- Physiology
- Growth
- Metabolism
- Behavior

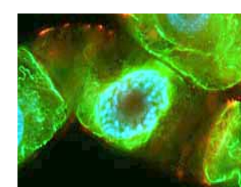
How does space affect development and life cycles of organisms?



- Reproduction
- Critical periods
- Life span effects

How do systems of organisms and their interactions change in space?

- Microbial populations
- Species interactions
- Crew health/life support implications



Example of ISS Research: Liver Cell Research, StelSys, Inc.

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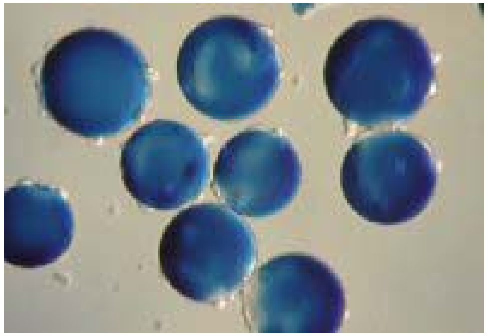
(Increment 5)

Dr. Albert Li, Ph.D., StelSys, Inc., Baltimore, Md.

A Baltimore-based biotechnology research company, StelSys LLC, in cooperation with NASA, is exploring specific research areas that benefit from liver cell research aboard the ISS.

Besides offering new insight into maintaining the health of humans living and working in space, research in this area could lead to earlier and more reliable **drug-candidate screening for patients in need of liver and kidney treatments** prior to transplant. According to Stelsys, it could also accelerate development of new life-saving drugs by pharmaceutical companies.



- ***Question 2: What must we know about how space changes life forms, so that humankind will flourish?***
  - ***Question 2a: Does space affect life at its most fundamental levels, from gene to the cell?***

Example of ISS Research: Biomass Production System (BPS)

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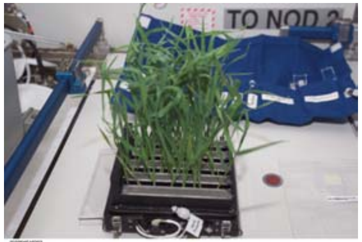
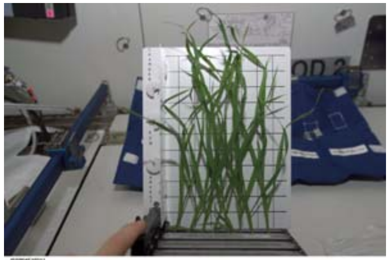
(Increment 4)



Photosynthesis Experiment and System Testing Operation (PESTO) - PI: Gary Stutte

Objective: determine effects of space on photosynthesis & carbohydrate metabolism of wheat.

- 6 on-orbit plantings, 7 on-orbit harvests.
- Over 280 individual plants were harvested and frozen for analysis upon return to earth
- 18 plants collected for microscopic analysis, 4 plants for genetic analysis
- The experiment was fully replicated in a ground control.

Initial assessment: there was no difference in growth rate or dry mass of wheat grown on the ISS. In addition, there was no difference in daily photosynthesis rates, leaf responses to canopy CO2 concentration, or light intensity.

This is the **first replicated data** obtained from plants grown under good environmentally controlled conditions to demonstrate that existing models using plants for advanced life support applications can be used without significant modification. While this has been the operating hypothesis for many years, the ISS provided the first opportunity to directly test this hypothesis in a scientifically credible manner.

- ***Question 2: What must we know about how space changes life forms, so that humankind will <u>flourish</u>?***
  - ***Question 2b: How does long-term exposure to space affect organisms?***

Food Production: What are the Optimum Growth Conditions?

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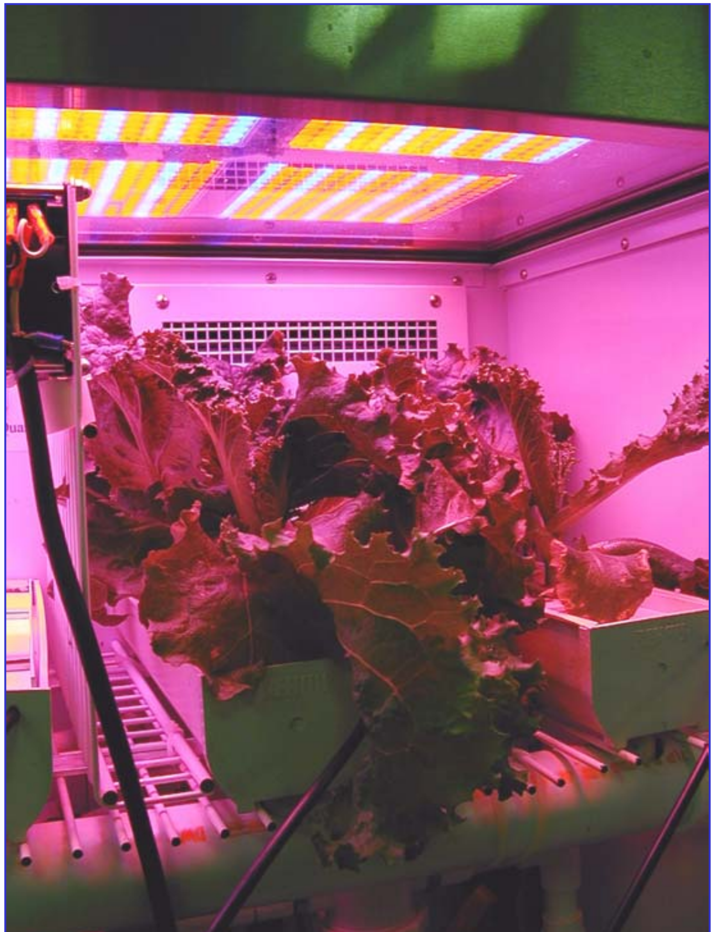

Lettuce growing under red and blue LED's.

Peanuts growing under light transmitted via fiber optics.

Sweet Potatoes growing under high pressure sodium lights.

Our Current Orbit – And Beyond

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Question 3: What new opportunities can our research bring to <u>expand</u> understanding of the laws of nature and <u>enrich</u> lives on Earth?

***Question 3a:** How does the space environment change the behavior of <u>physical and chemical processes</u> and the technologies that rely on them?*

***Question 3b:** What can we learn about the organizing principles from which <u>structure and complexity</u> arise in nature?*

***Question 3c:** Where will space research advance our knowledge of the <u>fundamental laws</u> governing time and matter?*

***Question 3d:** What are the fundamental physical, chemical, and <u>biophysical mechanisms</u> that drive the cellular and physiological behavior observed in the space environment?*

***Question 3e:** How can we create <u>research partnerships</u> that support national goals, such as contributing to economic growth and sustaining human capital in the areas of science and technology?*

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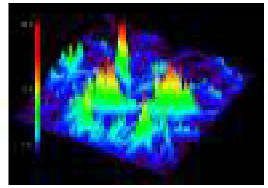
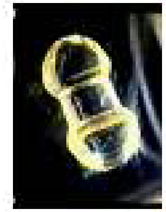
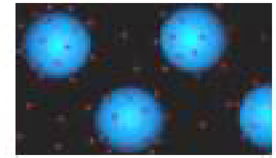
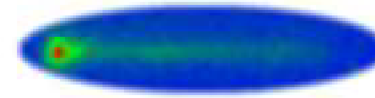
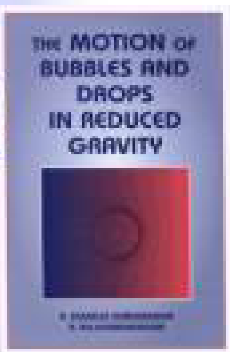
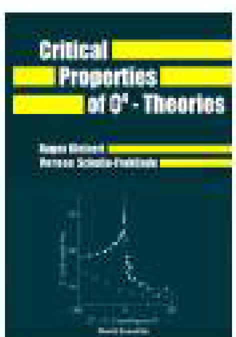
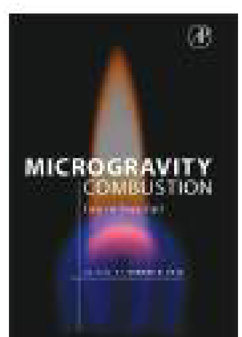





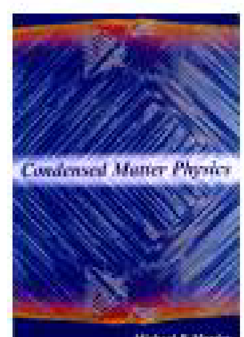

Physical Sciences Programs In the Office of Biological and Physical Research

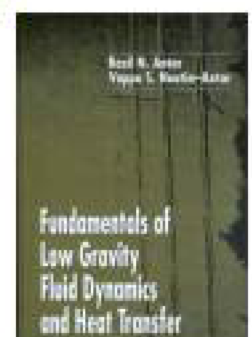
E. Trinh
NASA HQ

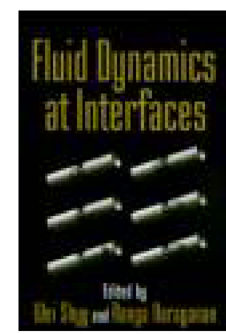






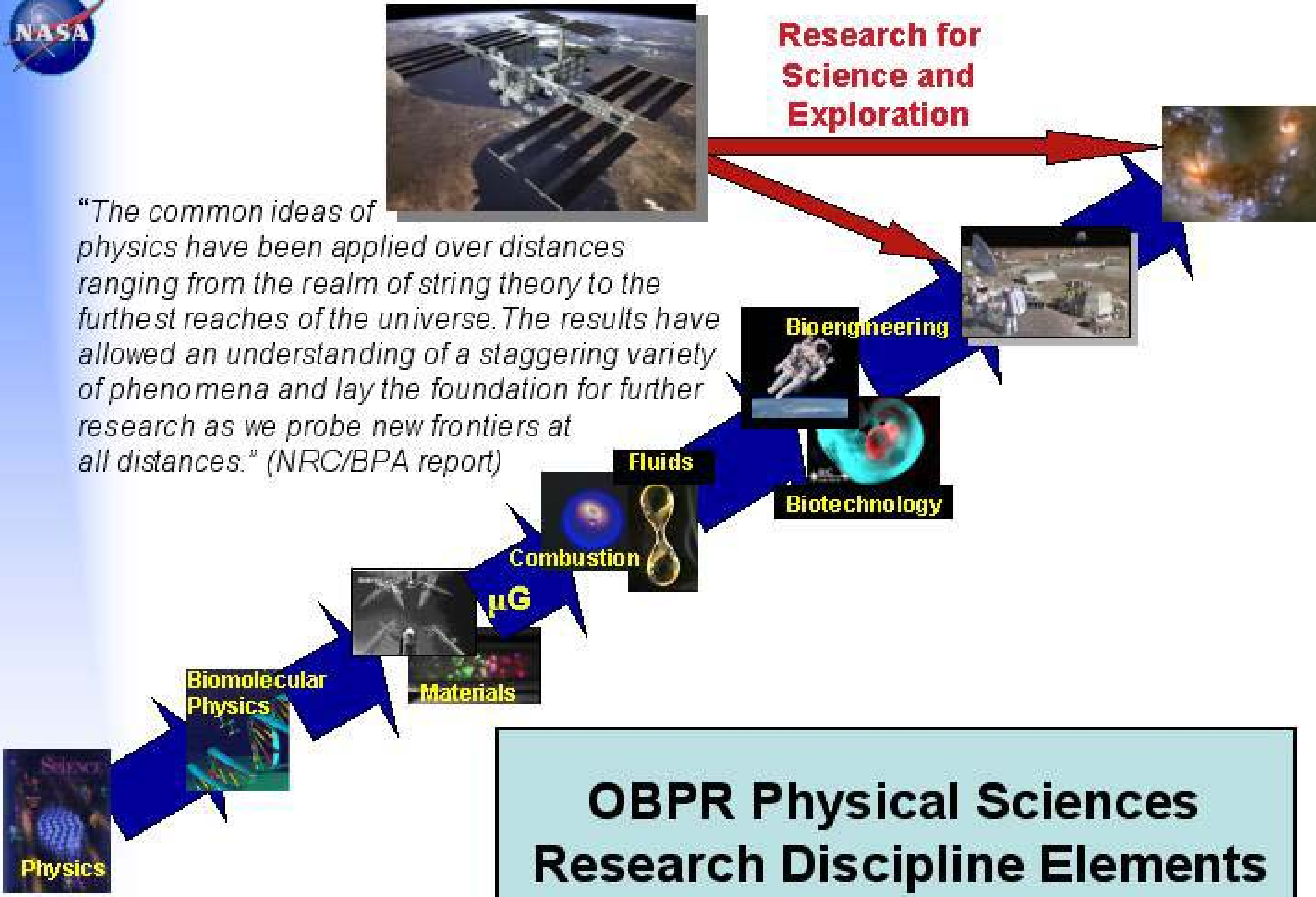






OBPR Physical Sciences Research Discipline Elements

"The common ideas of physics have been applied over distances ranging from the realm of string theory to the furthest reaches of the universe. The results have allowed an understanding of a staggering variety of phenomena and lay the foundation for further research as we probe new frontiers at all distances." (NRC/BPA report)



Example of ISS Research: Physics of Colloids in Space

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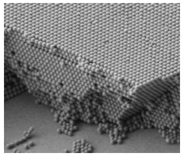
- **Photonics: replace electronics for next-generation communication & computing**
    - Promises faster speed, easier thermal control, smaller sizes
    - Stumbling block: need to guide light through complex, 3D nano-scale structures that serve as optical switches, splitters, etc – how to make such structures?



3-D crystallized structure from colloids

- **Goal: understand and control ‘self-assembling’ structures**

On ISS, behavior not possible to be observed on Earth: Binary colloid crystallization; spontaneous demixing of colloid-polymers; gravity affects the size and morphology of these structures

- **Early Detection of Cataracts – and More**
    - A technique in this experiment was adapted to detect cataract growth, and went into clinical testing at the National Eye Institute in 1999. NEI co-funds the development now.
    - NIH highlighted it to Congress in 2001 as a key technology.
    - Early detection allows assessment of drug therapies.
    - Fifty million people annually are affected by cataracts.
    - The instrument is currently being adapted to painlessly identify people with diabetes, other eye disease, or Alzheimer’s disease.

- ***Question 3: What new opportunities can our research bring to and <u>expand</u> our understanding of the laws of nature & <u>enrich</u> lives on Earth?***
    - ***Q. 3b: What can we learn about the organizing principles from which <u>structure and complexity</u> arise in nature?***

Our Current Orbit – And Beyond

Question 4: What technology must we create to <u>enable</u> the next explorers to go beyond where we have been?

- ***Question 4a:*** *How can we change spacecraft systems to lessen the required up-mass, volume, and power?*
- ***Question 4b:*** *How can technology help human productivity and well being during extended isolation from earth?*
- ***Question 4c:*** *How can we ensure that the crew is living in a safe and comfortable environment?*
- ***Question 4d:*** *What is the optimum way to support environmental health for crewmembers in space?*

Fire Safety : Benefits to Date, and Planned ISS Research and Technology

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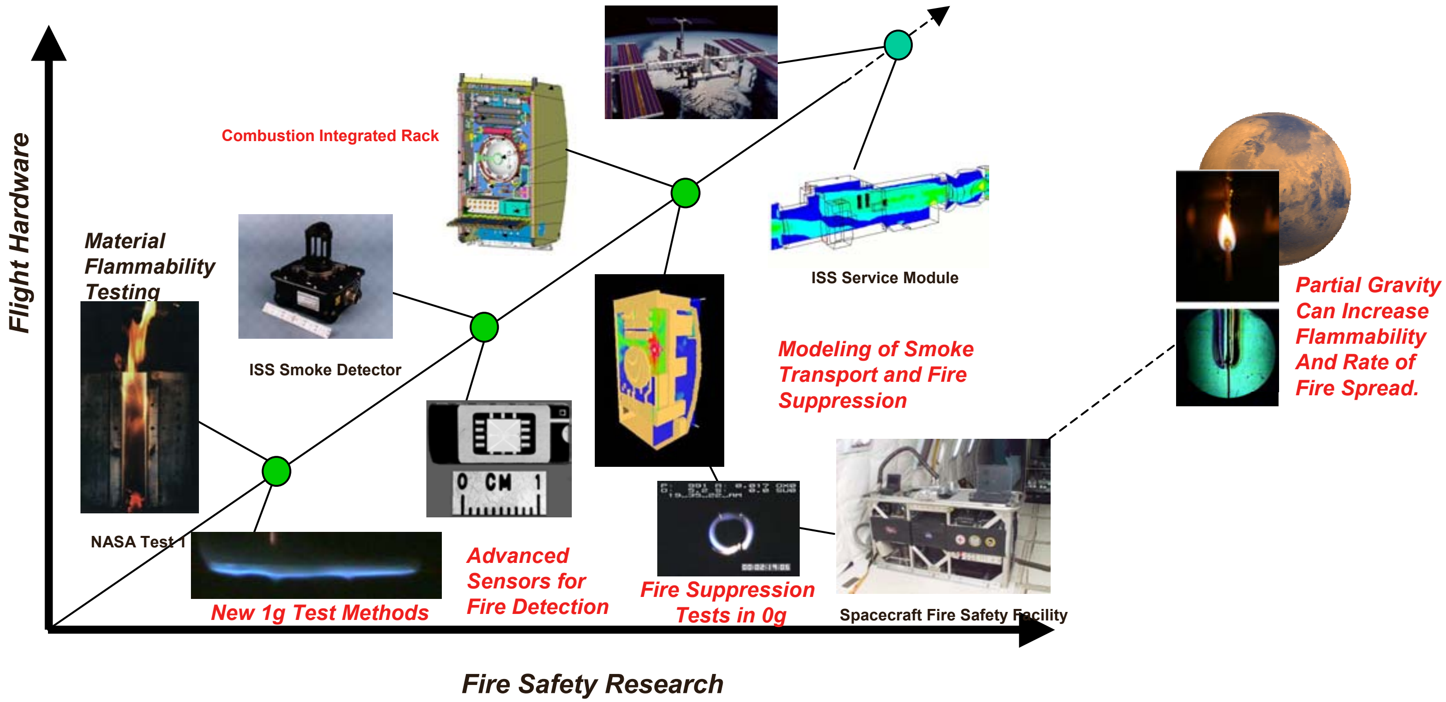
Previous applications of research findings to NASA's spacecraft fire practices and policies:

- Shut off ventilation flow upon start of fire event, rather than deploy a fire extinguisher.
- Recognition that margin of safety presupposed for material flammability in microgravity is in fact absent.
- Recognition that smoke particles in microgravity are different, changing the needed sensitivity in smoke detectors onboard spacecraft (and then tested the ISS and STS smoke detectors against 0g smoke).



- *Question 4: What technology must we create to enable the next explores to go beyond where we have been?*
  - *Question 4c How can we ensure that the crew is living in a safe and comfortable environment?*

Evaluating Technology Investments
Example: Mars Human Mission

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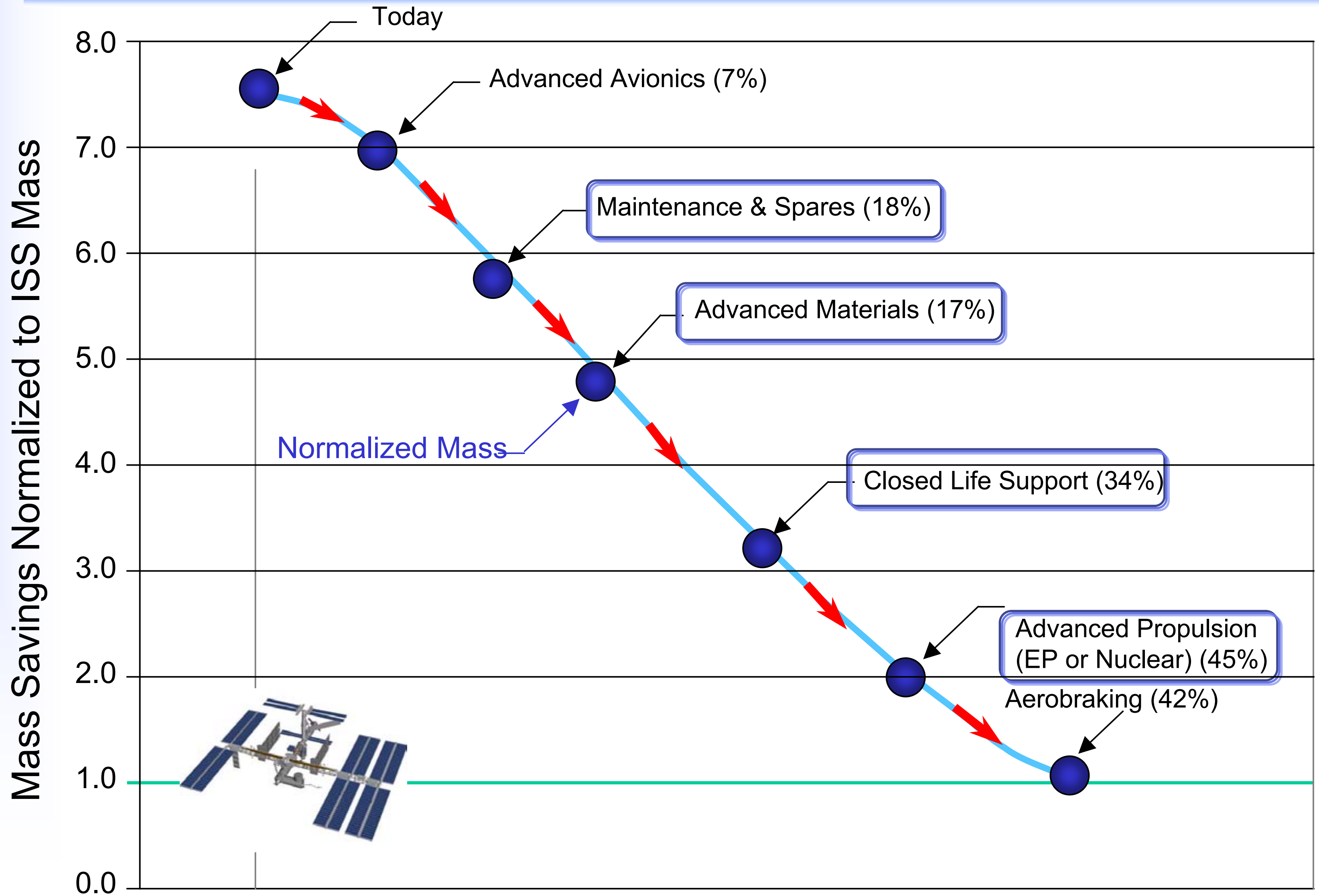

- ***Question 4: What technology must we create to enable the next explorers to go beyond where we have been?***
  - ***Question 4a: How can we change spacecraft systems to lessen the required up-mass, volume, and power?***

Example of ISS Flight Technology: The World's Smallest & Lightest Mass Spectrometer

(Increment 2 & subsequent)

- The mass spectrometers being flown on the Galileo mission to Jupiter and the Cassini mission to Saturn weigh 20 to 25 pounds and consume about 25 watts of power.
- NASA scientists have developed a miniature high-performance mass spectrometer that weighs about three pounds and consumes 15 watts.
- The miniature mass spectrometer, named the Trace Gas Analyzer (TGA), was delivered to the ISS in February 2001.
- Its primary use aboard the ISS is to detect leaks of ammonia and rocket propellant.

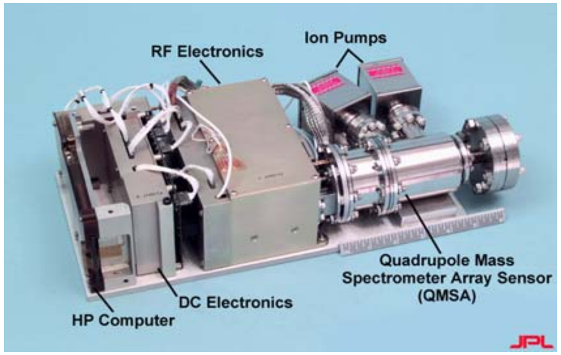

Figure 1. Basic components of the quadrupole sensor unit within the Trace Gas Analyzer (TGA).

Figure 2. The TGA prior To launch on STS-98 (1/01).

- ***Question 4: What technology must we create to <u>enable</u> the next explorers to go beyond where we have been?***
  - ***Question 4a: How can we change spacecraft systems to lessen the required up-mass, volume, and power?***
  - ***Question 4d: What is the optimum way to support environmental health for crewmembers in space?***

Example of Planned ISS Research: In-Space Fabrication for Exploration

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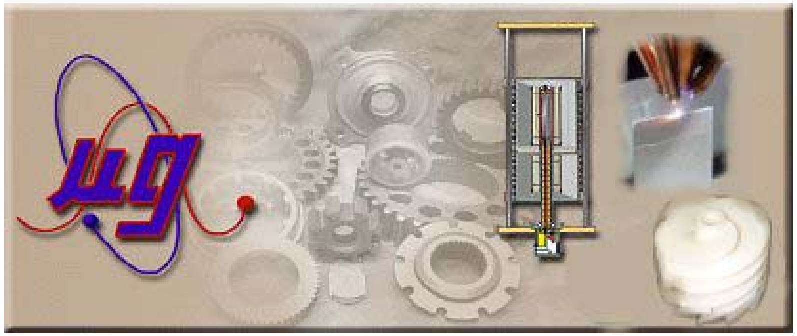
(Future Increment)

- ***In-Space Fabrication - The Ultimate in "Just-In-Time Manufacturing"***
  - **The ability to make and repair space hardware during a mission enables a "just-in-time" approach rather than a "just-in-case" approach.**
    - Reduces reliance on spare parts inventory
    - Provides timely capability to meet unanticipated requirements e.g. repair
    - Reduces need for re-supply from Earth
    - Enables new technologies for deep space missions. Parts or system components made in-space will not need to survive launch and can be assembled and deployed in space
    - Represents a critical element in evolution of autonomous exploration capability.

"Further technology development and actual implementation of the technology require that considerable research be done in the area of micro-structural control. The research is necessary to learn how to control the process to allow tailoring the microstructure of each part manufactured, thus ensuring that the resulting properties are appropriate for the desired application." Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies, NRC CMGR, 2000



- ***Question 4: What technology must we create to <u>enable</u> the next explores to go beyond where we have been?***
  - ***Question 4a: How can we change spacecraft systems to lessen the required up-mass, volume, and power?***

Our Current Orbit – And Beyond

Question 5: How can we educate and inspire the next generations to take the journey?

- ***Question 5a:*** *Educational Outreach*
- ***Question 5b:*** *Public Outreach*

Examples: Public & Educational Outreach Accomplishments

Space Research Newsletter

Quarterly newsletter for the Office of Biological and Physical Resarch. It contains articles, news and events on OBPR research activities.

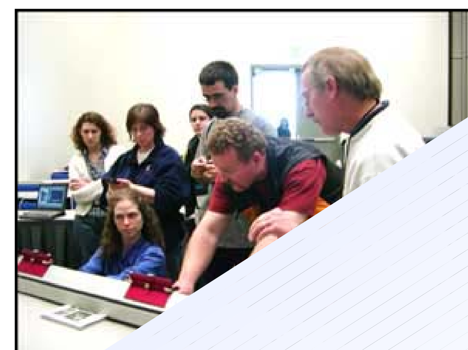
Countdown to Launch

Dr. Khalid Alshibli, Project Scientist, talks to students about the Mechanics of Granular Materials (MGM) experiments and hardware during the Countdown to Launch (STS-107)

OBPR Web Site

SpaceResearch.nasa.gov

Educational Conference



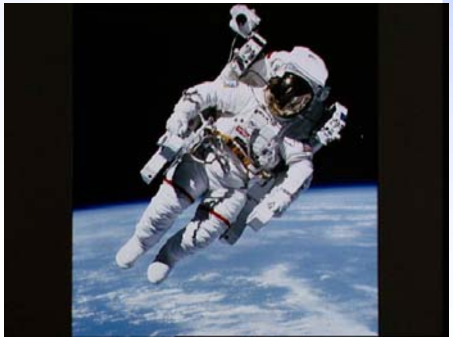
E[illegible] ...ional Science [illegible] Association (NSTA) annual conference take part in a workshop using an air track to simulate how weight is determined in a microgravity environment.

It All Requires People, Payloads, Power and Persistence in the ISS Laboratories!

OBPR

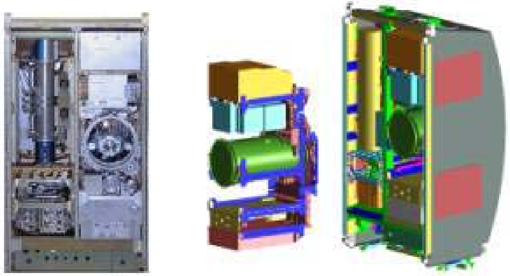
SpaceResearch.nasa.gov

Office of Biological & Physical Research



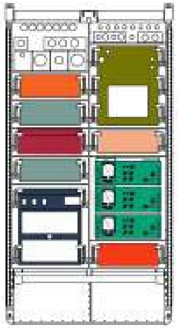
Combustion Integrated Rack (CIR) and insert

Materials Science Rack 1 and Insert (MSRR-1)



Microgravity Science Glovebox (MSG) Experiment

Low-Temperature MicroG Physics Facility (LTMPF)



Biotechnology Research Facility (BTF)

The Organizing Questions ...The OBPR Mission

Humans will extend the exploration of space. To prepare for and hasten the journey, OBPR must answer these questions through its research, principally on the ISS:

How can we assure the survival of humans traveling far from earth?

What must we know about how space changes life forms, so that humankind will flourish?

What new opportunities can our research bring to expand our understanding of the laws of nature and enrich lives on Earth?

What technology must we create to enable the next explorers to go beyond where we have been?

How can we educate and inspire the next generations to take the journey?